Claims

What is claimed is:

1. A method for determining the operating health of a hydraulic system, the method comprising the steps of:

determining a plurality of operating parameters of the hydraulic system during operation of the hydraulic system;

determining an estimated working condition value of the hydraulic system;

modifying the estimated working condition value as a function of the operating parameters; and

determining the operating health of the hydraulic system as a function of the working condition value.

2. The method of claim 1, wherein the working condition value is indicative of an effective bulk modulus value of at least part of the hydraulic system.

3. The method of claim 1, wherein the working condition value is indicative of a cavitation or entrapped air condition within the hydraulic system.

4. The method of claim 1, wherein the working condition value is indicative of an amount of leakage within at least part of the hydraulic system.

5. The method of claim 1, further comprising determining at least a second working condition value as a function of one or more of the operating parameters.

6. The method of claim 5, wherein:

at least one of the working condition values is indicative of an effective bulk modulus value of at least part of the hydraulic system; and

at least another of the working condition values is indicative of an amount of leakage within at least part of the hydraulic system.

7. The method of claim 5, wherein:

at least one of the working condition values is indicative of a cavitation or entrapped air condition within at least part of the hydraulic system; and

at least another of the working condition values is indicative of an amount of leakage within at least part of the hydraulic system.

8. The method of claim 1, wherein:

the step of determining operating parameters includes determining an operating pressure of a fluid drive member; and

the estimated working condition value is modified as a function of the operating pressure of the fluid drive member.

9. The method of claim 8, wherein:

the step of determining operating parameters includes determining an operating speed of a fluid drive member; and

the estimated working condition value is modified as a function of the operating speed of the fluid drive member.

10. The method of claim 1, wherein:

the step of determining operating parameters includes determining operating pressures of first and second fluid drive members; and

the estimated working condition value is modified as a function of the operating pressures of the first and second fluid drive members.

11. The method of claim 10, wherein:

the step of determining operating parameters includes determining an operating speed of the first fluid drive member and determining an operating speed of the second fluid drive member; and

the estimated working condition value is modified as a function of the operating speed of the first fluid drive member and as a function of the operating speed of the second fluid drive member.

12. The method of claim 11, wherein the step of determining operating parameters includes determining a swashplate angle; and

the estimated working condition value is modified as a function of the swashplate angle.

13. The method of claim 1, further comprising:

comparing the working condition value to one or more predetermined working condition values; and

determining the operating health of the hydraulic system as a function of the working condition value and the one or more predetermined working condition values.

14. The method of claim 1, further comprising:

determining a plurality of working condition values over a period of time; and

evaluating the working condition values to detect or predict a change in the operating health of the hydraulic system.

15. The method of claim 1, wherein:

the step of determining a plurality of operating parameters includes determining a reference operating parameter; and

the step of modifying the estimated working condition value includes modifying the estimated working condition value as a function of the reference operating parameter.

16. The method of claim 15, further including:

determining a model operating parameter as a function of the estimated working condition value;

wherein the step of modifying the estimated working condition value includes modifying the estimated working condition value as a function of the relationship between the model operating parameter and the reference operating parameter.

17. The method of claim 16, wherein the step of determining a model operating parameter includes determining a model operating parameter as a function of one or more of the operating parameters.

18. The method of claim 16, further comprising repeating the step of modifying the estimated working condition value until the model operating parameter bears a desired relationship with the reference operating parameter.

19. A method for determining the operating health of a hydraulic system, the method comprising the steps of:

determining a plurality of operating parameters of the hydraulic system during operation of the hydraulic system;

using the operating parameters to determine one or more working condition values of the system;

wherein:

a first one of the one or more working condition values is indicative of an effective bulk modulus value of an operating fluid within at least part of the hydraulic system.

20. The method of claim 19, wherein a second one of the one or more working condition values is indicative of an amount of leakage within at least part of the hydraulic system.

21. The method of claim 19, wherein the first working condition value is indicative of an effective bulk modulus value of an operating fluid within a hydraulic pump.

22. The method of claim 19, wherein the first working condition value is indicative of an effective bulk modulus value of an operating fluid within a hydraulic actuator.

23. The method of claim 20, wherein at least one of the working condition values is indicative of a cavitation or entrapped air condition within at least part of the hydraulic system.

24. An apparatus for determining the operating health of a hydraulic system, the apparatus comprising:

a plurality of sensors operably connected to the hydraulic system and operable to indicate operating parameters of the hydraulic system during operation of the hydraulic system; and

at least one processor operably connected in electrical communication with the sensors, the at least one processor being operable to determine one or more working condition values as a function of the actual operating parameters, a first one of the one or more working condition values being indicative of an effective bulk modulus value of an operating fluid within at least part of the hydraulic system.

25. The apparatus of claim 24, wherein a second one of the one or more working condition values is indicative of an amount of leakage within at least part of the hydraulic system.

26. The apparatus of claim 24, wherein:

the hydraulic system includes first and second fluid drive members disposed in fluid communication with each other; and

the plurality of sensors includes a first sensor operably connected with the at least one processor and operable to indicate an operating pressure of the first fluid drive member and a second sensor operably connected with the at least one processor and operable to indicate an operating pressure of the second fluid drive member.

27. The apparatus of claim 26, wherein the plurality of sensors further includes:

a third sensor operably connected with the at least one processor and operable to indicate an operating speed or position of the first fluid drive member; and

a fourth sensor operably connected with the at least one processor and operable to indicate an operating speed or position of the second fluid drive member.

28. The apparatus of claim 24, wherein:

the hydraulic system includes a hydraulic pump and a hydraulic actuator disposed in fluid communication with the hydraulic pump; and

the plurality of sensors includes:

a first sensor operably connected with the at least one processor and operable to indicate an operating pressure of the pump;

a second sensor operably connected with the at least one processor and operable to indicate an operating speed of the pump;

a third sensor operably connected with the at least one processor and operable to indicate an operating pressure of the actuator; and

a fourth sensor operably connected with the at least one processor and operable to indicate an operating speed or position of the actuator.

29. The apparatus of claim 28, wherein the actuator is a hydraulic piston and cylinder arrangement.

30. The apparatus of claim 28, further comprising a swashplate;

wherein the plurality of sensors includes a fifth sensor operably connected with the at least one processor and operable to indicate a swashplate angle.